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by

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INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
FOREST SERVICE
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SPIRAL GRAIN--A CAUSE OF POLE TWISTING

Charles A. Wellner and David P. Lowery

Pole producers and pole users have contended with spiral grain in poles and the twisting of poles that have been in service for a number of years without fully appreciating the cause-and-effect relation between the two. Pole producers have rejected poles because the slope of grain failed to meet specification requirements, and pole users have had to pay for costly pole replacement or line repairs because poles twisted in place. It has been generally believed that twisting or misalignment of crossarms was caused either by uneven pull on the wires by line crews during construction or repair work, by heavy icing, or by wires broken by falling trees. Although the effect of grain deviations on the warping of boards and timbers has long been understood, the influence on wood used in the round has not been as apparent or as obvious.

The present American Standards Association specification for poles limits, among other things, the slope of grain that can be tolerated on the pole's surface. The specification states that for a pole 30 feet or shorter the maximum spiral grain permitted shall be one complete spiral in any 10 feet; for poles 35 to 45 feet inclusive, one complete spiral in any 16 feet; and for poles 50 feet or longer, one complete spiral in any 20 feet.

This paper describes research¹ on the occurrence of spiral grain and the effect of spiral grain on the stability of poles in service.

SURVEY OF LITERATURE

Spiral grain in trees has been noted and reported upon rather extensively. Excellent summaries of the literature have been prepared by Noskowiak (13), Nicholls (10), Northcott (12), and Bannon (2).²

Spiral grain is a common feature of tree growth and has been reported in nearly 200 species of hardwoods and softwoods. There is some evidence to indicate that spiral grain is a genetic characteristic that may be transmitted from parents to offspring (4, 5, 6). So common is the occurrence of spiral grain that Northcott (11) has advanced the hypothesis that spirality is the normal growth pattern and that straight grain is a transitory phase of spiral grain. Rudinsky and Vité (15) classified the water-conducting systems in trees into five groups, four of which contain spiral grain.

Because severe spiral grain has a profound influence on the strength and workability of timber (1, 14, 17), it is of great interest to forest managers and wood technologists. Two investigators have reported on the interrelationship of spiral grain and pole twisting. Krogh's (9) studies in South Africa were designed to show the relation between spiral grain and the amount of twisting that takes place in poles due to weather changes and the effect of

¹The authors express their appreciation to the following men who assisted in planning or conduct of fieldwork: I. V. Anderson, Frank T. Bailey, Jr., Henry H. Webster, and Peter F. Stickney. They also express their gratitude and thanks to the cooperating companies for financial assistance, frequent suggestions and ideas, and many courtesies and other help given during conduct of the various studies.

²Underlined numbers in parentheses refer to Literature Cited at the end of this report.

preservatives on the amount of twisting. Hans Burger's (3) studies in Switzerland established a correlation between spiral grain and poles twisting in service.

COOPERATIVE STUDIES³

Because of the lack of information in this country on pole twisting, several studies were made of various phases of the problem in cooperation with pole producers. Each of these studies is here discussed separately. The first study set out to determine what might be the cause of twisting of poles in service. It soon pinpointed spiral grain, and all subsequent studies were concerned with this property. The second study attempted to find a practical method for detecting spiral grain in unpeeled poles. The third study surveyed the occurrence of spiral grain in poles in four pole yards in northern Idaho and northeastern Washington. The fourth study tried to determine the effects of altitude and stand density on spiral grain in live pole-size trees. The fifth study established a larch pole farm at Newport, Washington, to determine the effect of spiral grain on twisting of poles. A sixth study, to be reported later, established a pole farm at Libby, Montana, somewhat similar to the Newport pole farm; but it included three species rather than only the one species at Newport. Western larch (*Larix occidentalis* Nutt.) was chosen as the study species for all five studies reported here because it was available at the different pole-processing plants and because of its wide acceptance as a pole species. However, it is believed that the information obtained applies to other pole species.

Relation Between Spiral Grain and Twisting

The first study was made to determine, if possible, what caused poles to twist when in service in power transmission lines. This investigation, made in the spring of 1952, involved the inspection of poles in several transmission lines. The poles were examined in detail to discover any possible cause of twisting, and spiral grain appeared to be the major cause. Consequently the following discussion is concerned only with this property.

Two hundred and ninety western larch poles in four transmission lines were examined during this study. The lines were selected on the basis of historical knowledge of the poles used in each line. For each pole, information was obtained on the relation between the degree of spiral grain on the pole surface and the twisting of the pole in place. In addition, historical data provided information regarding the effect of seasoning on the subsequent amount and direction of twisting in the spiral-grained poles.

The lines inspected were typical; that is, the pole lengths ranged from 30 to 60 feet with half of the poles being under 45 feet and the remainder over 45 feet in length. The poles had all been butt treated; however, the length of air seasoning time, prior to treatment, varied among the different pole lines. The poles in one line had been butt treated green; in a second line, they had been air seasoned 6 months prior to treatment; in the third line, the poles had been air seasoned 22 months before butt treating; no definite seasoning information was available on the poles in the fourth line.

³The following companies cooperated in the first, second, third, and fifth studies described here: Poles, Inc., Spokane, Wash.; B. J. Carney and Co., Spokane, Wash.; and Schaefer-Hitchcock Co., Sandpoint, Idaho. The J. Neils Lumber Co., Libby, Mont., cooperated in the fourth and sixth studies.

Results of this pole line study showed that left spiral⁴ occurred about three times as frequently as right spiral. Generally, the pole twisted in the same direction as the spiral and the few exceptions were believed to have been due to line pull. Left-spiraled poles seemed to distort more than right-spiraled poles. However, extreme distortion was always associated with severe spiral grain on the pole's surface. Many poles showed spiral grain on the surface but did not twist in place; this indicated that seasoning might have reduced the distortion forces.

The effect of seasoning on the three lines for which information was available is shown in the following comparison:

<u>Transmission</u> <u>line</u>	<u>Air</u> <u>seasoning</u> <u>period</u> (Months)	<u>Proportion of poles</u> <u>with distortion greater than</u> <u>3 percent</u> ¹ (Percent)
1	0	26
2	6	22
3	22	2

¹In percent of pole circumference at ground line.

On some individual poles, the spiral angle was not the same along the entire length. No correlation could be established between the change of spiral angle and the pole's distortion. However, the relation between the average degree of spiral grain and the amount of distortion was definite; as the average degree of spirality increased, the amount of distortion increased (table 1).

Table 1. --Relation of distortion to spiral grain classes in four transmission lines

Spiral ratio class ¹	: Left-spiraled grain			: Right-spiraled grain			: Right-spiraled grain		
	: Left distortion :			: Left distortion :			: Right distortion :		
	: in degrees : Total			: in degrees : Total			: in degrees : Total		
	: 0-5	: 5-10	:	: 0-5	: 5-10	:	: 0-5	: 5-10	:
----- Number -----									
1: 1- 10	7	9	16	0	0	0	0	0	0
1: 11- 20	26	5	31	1	0	1	4	0	4
1: 21- 30	20	2	22	5	0	5	6	0	6
1: 31- 40	17	3	20	4	0	4	0	0	0
1: 41- 50	17	1	18	3	0	3	6	0	6
1: 51-100	28	3	31	9	0	9	14	1	15
1:101-150	20	0	20	3	0	3	5	0	5
1:151-200	7	0	7	3	0	3	2	0	2
1:201+	23	0	23	1	0	1	5	0	5
No spiral	25	0	25	0	0	0	1	0	1
Total	190	23	213	29	0	29	43	1	44

¹In terms of 1 inch of deviation for indicated inches measured along the longitudinal axis of the pole. For example, 1:10 means 1 inch of grain deviation in 10 inches along the longitudinal axis of the pole.

⁴As used in this paper, "left spiral" means that as you face an upright pole, grain spirals to the left as you look from the bottom to the top of the pole.

Detection of Spiral Grain Prior to Debarking

No reliable way has been found to date for detecting presence or absence of spiral grain in a tree or pole before debarking. A practical method for doing this could effect considerable savings for pole producers because buyers could use greater selectivity in purchasing poles, and the expenses of producing and processing unsuitable material could be avoided.

To determine the feasibility of detecting spiral grain, two methods were tried in 1952 at pole yards in Newport, Washington. In the first, the outer bark surface of 29 poles was examined and an attempt was made to determine the direction of the bark furrows with reference to the longitudinal axis of the pole. The direction was then translated into terms of spiral ratio. The direction and degree of spiral were recorded. After machine peeling, the actual direction and slope of grain were determined by scribing the surface with a TECO slope of grain detector.⁵ Measurements were made at the top, middle, and butt of each pole, and were averaged.

In the second method, the outer bark was removed with a drawknife at various places along the pole's length. At each debarked area, a narrow strip of the thin inner skinlike bark was peeled off and the direction of peel noted. These directions were then translated into spiral ratios and averaged to give a predicted direction and degree of spiral for each pole. After the pole was peeled, the actual slope of grain was determined as for the first method--using a TECO slope of grain detector. The 28 poles examined in this manner made a total of 57 poles included in the study.

Results of this study showed that it was impossible to predict occurrence of severe spiral grain (i.e., 1:20⁶ or more severe) with any consistent degree of success. In the first method (visual examination of the bark), one pole having severe spiral grain was not detected prior to peeling, while another pole, believed to have severe spiral grain, did not fall into this category. With the second method (peeling of the inner bark), five poles actually had severe spiral grain and five poles were predicted to have this characteristic. However, only two of the poles that had severe spiral grain were properly identified.

Somewhat better success was attained in predicting the direction of spiral without reference to the degree of grain slope. This was particularly true for the inner bark examination method, by which direction of spiral was correctly predicted in 86 percent of the poles. The comparable percentage for outer bark examination was 55 percent.

⁵ Product of Timber Engineering Co., Wash., D.C. Use of trade name herein does not imply endorsement by the U.S. Forest Service.

⁶ One inch of grain deviation in 20 inches measured along the longitudinal axis of the pole.

Occurrence of Spiral Grain in Poles

A third study, made in 1952, was concerned with the frequency of occurrence of spiral grain in poles. Poles totaling 800, either green or air seasoned 1 year, were examined in four pole yards of the cooperators. These yards were located at Spokane and Newport, Washington, and at Priest River and Sandpoint, Idaho. One hundred poles were examined during each of two visits at the individual yards in order to obtain a representative production sample. The direction and degree of spiral grain were measured at the top, middle, and butt surfaces and the measurements for each pole were averaged.

Of the 800 poles examined, only 1 percent (7 poles) had a slope of grain of 1:10 or more severe (table 2). Six and one-half percent of the poles (53 in number) had a slope of grain between 1:11 and 1:20. Forty-eight percent of the poles were practically straight grained, i.e., 1:201 or more.

Table 2. --Spiral-grained poles classified by pole yard and spiral ratio classes

Spiral ratio : class :	Yard				All yards	
	A	B	C	D	Number	Percent
	Number					
1: 1- 10	3	1	1	2	7	1.0
1: 11- 20	15	9	13	16	53	6.5
1: 21- 50	53	32	28	38	151	19.0
1: 51-100	34	32	30	19	115	14.0
1:101-150	14	26	10	10	60	7.5
1:151-200	8	4	10	11	33	4.0
1:201+ ¹	75	96	108	104	381	48.0
Total	200	200	200	200	800	100.0

¹ Poles in this class are practically straight grained.

Poles with spiral grain to the left occurred with greater frequency than poles with a slope of grain to the right (table 3). Sixty-six percent of the poles examined had left-spiraled grain as compared with 34 percent that had right-spiraled grain. The left-spiraled grain was even more common where the spiraling was severe. All poles with a slope of grain of 1:10 or more severe had left spiral, and 88 percent of the poles having a slope of grain of 1:20 or more severe were left spiraled.

Spiral grain had no apparent relation to pole circumference; there was no significant difference between pole groups of classes 1 to 4 and 5 to 7.⁷

Variation in the slope of grain along the pole's length was common; maximum divergence from the longitudinal occurred most frequently near the top of the pole (table 4). Some variation in the slope of grain was observed in 378 out of 400 poles for which these data were recorded. The variation was usually relatively small, but spiral ratios as dissimilar as 1:720 and 1:20 were observed in a single pole.

⁷ Pole classes are based on circumference at the groundline and top; the lower the number the greater the circumference.

Table 3. --Poles classified by direction of grain and spiral ratio classes

Spiral ratio class	Direction of grain			
	Left	Right	Left	Right
	Number		Percent	
1: 1- 10	7	0	100	0
1: 11- 20	46	7	87	13
1: 21- 50	103	48	68	32
1: 51-100	73	42	63	37
1:101-150	40	20	67	33
1:151-200	13	20	39	61
1:201+ ¹	245	136	64	36
Total	527	273	66	34

¹ Poles in this class are practically straight grained.

Table 4. --Section of pole in which maximum divergence of grain occurred,
by pole yard

Section	Yard				All yards	
	A	B	C	D		
	Number				Number	Percent
Top	48	37	45	38	168	44
Middle	20	25	31	21	97	26
Butt	27	29	22	35	113	30
Total	95	91	98	94	378	100

Forty-four percent (168) of the poles exhibited maximum divergence of grain in the top section of the pole. Percentages of the poles exhibiting maximum grain divergence in the middle and butt sections were 26 and 30 percent, respectively.

Effects of Position on Slope (Altitude) and Stand Density on Spiral Grain of Living Trees of Pole Size

Still another study was made in the summer of 1953 to determine whether spiral grain in living western larch trees of pole size showed any relation either to position on slope or density of stand. Study plots, each consisting of 25 pole-size trees, 6 to 18 inches d.b.h., were established in dense and open stands on lower, mid, and upper slopes at two locations. One of these locations was the Priest River Experimental Forest within the Kaniksu National Forest in northern Idaho, and the other was near Big Creek Baldy Mountain in the Kootenai National Forest in northwestern Montana. Each tree was measured and described, and slope of grain was measured by means of a bolaxis (16) at 16 feet above groundline on a face where the bark had been peeled away with a drawknife. Table 5 summarizes distribution of the 300 trees measured in this study.

Table 5. --Distribution of sample trees by direction and degree of grain slope for each location, slope position, and stand density

Plot no.	Slope position	Elevation	Stand density	Grain slope direction			Grain slope ratio		
				Left	Right	Straight	1:10 or more severe	1:11 to 1:20	1:21 or less severe
		Feet	-----Number of trees-----						
KANIKSU PLOTS									
4	Upper	5,000	Dense	11	8	6	0	2	23
3	Upper	5,000	Open	6	19	0	3	8	14
5	Mid	3,900	Dense	5	19	1	0	3	22
6	Mid	3,900	Open	7	18	0	2	10	13
1	Low	2,400	Dense	9	15	1	0	2	23
2	Low	2,400	Open	8	15	2	0	3	22
Total				46	94	10	5	28	117
KOOTENAI PLOTS									
5	Upper	5,200	Dense	8	14	3	0	4	21
4	Upper	5,400	Open	5	19	1	1	8	16
6	Mid	4,200	Dense	8	13	4	0	6	19
3	Mid	4,200	Open	6	15	4	0	7	18
2	Low	3,200	Dense	6	17	2	1	9	15
1	Low	3,200	Open	20	5	0	3	6	16
Total				53	83	14	5	40	105
Total				99	177	24	10	68	222

Slope position had no apparent effect on either the direction or severity of grain slope (table 6).

Table 6. --Relation of direction and degree of spiral grain to slope position

Stand position	Grain slope direction :			Grain slope ratio		
	Left	Right	Straight	1:10 or more severe	1:11 to 1:20	1:21 or less severe
-----Number of trees-----						
Upper	30	60	10	4	20	76
Mid	26	65	9	2	26	72
Lower	43	52	5	4	22	74
Total	99	177	24	10	68	222

Stand density, on the contrary, appeared to affect severity of spiral grain (table 7). Of the 10 trees having a spiral grain ratio of 1:10 or more severe, 9 occurred in open-grown stands. Trees having a spiral grain ratio of 1:11 to 1:20 were also more numerous in open-grown stands.

Table 7.--Relation of direction and severity of spiral grain to stand density

Stand density	Grain slope direction			Grain slope ratio		
	Left	Right	Straight	1:10 or more severe	1:11 to 1:20	1:21 or less severe
-----Number of trees-----						
Open	52	91	7	9	42	99
Dense	47	86	17	1	26	123
Total	99	177	24	10	68	222

Although table 7 does not show any apparent effect of stand density on direction of spiral grain, a more detailed analysis of the data showed that stand density had a very marked effect. Western larch is a very intolerant species; as a result, stand density strongly affects both diameter growth rate and length of live crown. Although diameter growth rate was not measured, live crown length in percent of total tree height was recorded for each tree. All trees having a spiral grain ratio of 1:50 or more severe were sorted out and examined more critically. When the ratio of number of trees having left-hand spiral grain to the number of trees having right-hand spiral in each crown-length class was plotted over crown length, figure 1 resulted. This shows a very striking relation between crown length and direction of spiral grain. By inference, this figure suggests a definite relation between stand density--and hence diameter growth rate--and direction of spiral grain. Trees in open stands, i.e., trees with long crowns and rapid growth rate, tend to have grain that spirals to the left. Trees in very dense stands, i.e., trees with short crowns and slow diameter growth, tend to have grain that spirals to the right.

Experimental Pole Farm at Newport, Washington

A study designed to establish the correlation between spiral grain and the twisting of poles was installed at Newport, Washington, during August 1952. This consisted of 40 poles--2 replications in each of 20 categories. The selected poles represented four degrees of seasoning (green and air seasoned 1, 2, or 3 years) and five classes of spiral grain (straight, left severe, left moderate, right severe, and right moderate). The poles classified as "straight grain" had a slope of grain of 1:201+; moderate spiral had a slope of grain between 1:35 and 1:65; and severe spiral grain had a slope of grain less than 1:15. Distribution of the sample poles is shown in table 8.

The selected poles were either 40 or 45 feet in length and of pole class 3, 4, or 5. All poles were butt treated and set in the ground approximately $6\frac{1}{2}$ feet. The poles were positioned in two rows, extending east and west, on either side of a railroad rail, and approximately 6 feet from the rail. A pipe was attached at the crossarm position of each pole with the pipe end directly above the rail. A line and plumb bob was attached to each pipe end, and the iron rail was marked to show an original point for each pipe. Subsequent measurements were based on the departure from this reference mark (16).

Figure 1. --Relation of ratio of trees having left-hand spiral grain to trees having right-hand spiral grain to live crown length. Only trees with spiral grain ratio of 1:50 or more severe were included.

Table 8. --Distribution of sample poles by period of seasoning and spiral grain class

Period of seasoning	Grain classification ¹					
	Straight	Left spiral		Right spiral		
		Moderate	Severe	Moderate	Severe	
<hr style="border-top: 1px dashed black;"/> <div style="text-align: center;"><u>Pole numbers</u></div> <hr style="border-top: 1px dashed black;"/>						
Green	1, 2	3, 4	5, 6	7, 8	9, 10	
1 year	11, 12	13, 14	15, 16	17, 18	19, 20	
2 years	21, 22	23, 24	25, 26	27, 28	29, 30	
3 years	31, 32	33, 34	35, 36	37, 38	39, 40	

¹ Slope-of-grain classes were as follows: straight grain 1:201+, moderate spiral 1:35-65, and severe spiral 1:6-15.

Twist measurements were made four times during the first year following erection of the poles and thereafter at least twice a year for the next 4 years (table 9).

Table 9. --Average total distortion of poles classified by grain direction and amount of grain slope

Grain direction	: Jan. : : 1953 :	: Apr. : : 1953 :	: July : : 1953 :	: Aug. : : 1953 :	: Dec. : : 1953 :	: Apr. : : 1954 :	: Oct. : : 1954 :	: Feb. : : 1955 :	: Dec. : : 1955 :	: July : : 1956 :	: Dec. : : 1956 :
	----- Degrees -----										
Straight grain	1.97	1.97	3.85	5.31	5.33	4.18	6.55	5.36	6.45	6.72	7.56
Left moderate	3.45	2.75	7.04	10.12	11.48	9.74	13.91	12.44	14.77	15.04	17.47
Left severe	7.11	5.29	15.04	21.73	23.41	19.49	27.84	23.94	29.55	29.53	33.01
Right moderate	.76	.91	1.47	1.88	2.07	2.15	2.92	2.65	3.35	3.74	4.63
Right severe	2.17	1.33	3.08	5.11	5.81	5.65	7.88	7.15	8.51	6.68	8.65

In general, the poles not only showed progressive trends of increasing distortion from January 1953 to December 1956, but also showed some fluctuations, particularly between the fall or midwinter measurements and the spring measurements. The maximum distortion measurements for the individual poles are shown in table 10.

Table 10. --Direction of twist and maximum twist of poles in Newport pole test

Degree of seasoning	Grain classification					
	Straight	Left spiral		Right spiral		
		Moderate	Severe	Moderate	Severe	
	----- Degrees -----					
Green	¹ L	4.08	L21.67	L48.83	R 8.58	R17.17
	² R	2.58	L16.83	L38.00	R 2.50	R16.58
1 year	L	11.58	L14.00	L31.92	L10.00	R 5.67
	L	3.17	L10.67	L19.00	R 1.92	R18.83
2 years	L	18.17	L32.83	L43.00	L 3.33	R 4.83
	L	5.83	L13.42	L39.00	L12.50	R 2.75
3 years	L	7.83	L18.42	L42.00	R 1.50	R 2.83
	L	9.83	L 5.58	L 8.83	L 2.58	R 6.58

¹ L signifies twist to left and R twist to right.

² Poles are listed in the same order as in table 8.

These data show that the straight-grain poles and those with right-hand spiral grain of either moderate or severe slopes generally had less maximum twist than poles with left-hand spiral, irrespective of seasoning. Also, in most instances, as with the transmission line poles, the distortion was in the same direction as the grain spirality.

The variations in the maximum twist of the poles were primarily associated with the grain direction. That is, the factor of air seasoning the poles before setting showed no consistent effect on the maximum distortion (table 11).

Table 11. -- Analysis of variance of maximum twisting of poles at Newport pole farm

Source of variation in maximum distortion	Degrees of freedom	Sums of squares	Mean square	"F" value
Grain direction (Gd)	4	15,307,797	3,826,949	*3.976
Seasoning (S)	3	1,380,492	460,164	.478
Interaction (Gd $\times$ S)	12	2,561,135	213,428	.222
Within duplicates (error)	20	19,249,425	962,471	

*F.05 = 2.87, F.01 = 4.43.

Nonorthogonal comparisons of the pole maximum distortion by their grain-direction classification, irrespective of seasoning, are shown in table 12. This analysis indicates that only the left spiral-grained poles differed significantly and that severe left-spiraled poles distorted the most.

Table 12. -- Nonorthogonal comparisons of maximum distortions of poles by their grain direction

Nonorthogonal comparisons of maximum distortions	Sums of squares (1 d.f.)	"F" value ¹
Straight vs. right moderate	89,252	0.093
Straight vs. right severe	34,689	.036
Straight vs. left moderate	1,120,952	1.165
Straight vs. left severe	9,711,014	**10.090
Right moderate vs. right severe	235,225	.244
Left moderate vs. left severe	4,233,306	*4.398
Right moderate vs. left moderate	11,662,225	**12.117
Right severe vs. left severe	8,584,900	**8.920
Right severe vs. left moderate	761,256	.791
Right moderate) vs. (left moderate Right severe) vs. (left severe	18,382,656	**19.099

¹Error for calculating "F" value = 962,471 (d.f. = 20) from analysis of variance of maximum distortion.

*F.05 = 4.35.

**F.01 = 8.10.

These analyses establish the relation between distortion and spiral grain, particularly for left-spiraled poles. However, the data fail to explain satisfactorily the stability of the right spiral-grained poles. In an effort to isolate the factor or factors responsible, 10 of the study poles were selected for dissection and subsequent examination (table 13).

This sample was composed of four right-spiraled, four left-spiraled, and two straight-grained poles. In general, the sample was selected on the basis of either maximum or minimum distortion in the five slope-of-grain classifications. The four seasoning classes were also included in the sample.

Table 13. --Distribution of poles selected for transverse sectioning
by grain direction and seasoning

Seasoning	Grain classification					
	Straight	Left spiral		Right spiral		
		Moderate	Severe	Moderate	Severe	
Green	¹ 2-R 2.58		5-L48.83	7-R 8.58		
1 year						20-R18.83
2 years	21-L18.17	23-L32.83		28-L12.50		
3 years		34-L 5.58	36-L 8.83			39-R 2.83

¹ The number before the dash is the pole number, and the letter and numbers after the dash are direction and degrees of maximum distortion in the standing pole.

At the time the pole farm was terminated, these 10 sample poles were felled and sections approximately 12 inches long were cut about 8 feet from each pole end, and at the midpoint. The sections were identified as to pole number and location within the pole, and referenced in relation to the projecting pipe. The reference mark was also the longitudinal axis of the pole.

In the laboratory, the sections were split on a line extending from the reference mark through the pith, and the spirality on the split face was measured at 10-year growth increments using a device patterned after that developed by the Canadian Forest Products Laboratory (8, 11).

The measurements showed a wide variation in the slope of grain for sections from any one pole, as well as for sections from different poles. In general, the data conformed to those reported by other investigators (4, 7, 11, 14) in that the grain spiraled to the left initially when the tree was young, gradually decreased to zero, and then passed to an increasing right spiral. In only four of the 30 sections split was there an initial zero or right spiral that remained constant in direction.

The measurements explain the stability of the right-spiraled poles. Poles containing left spiral only are freer to respond to moisture content changes than are poles containing both left- and right-spiraled grain. In the latter case, the tendency of the left-spiraled grain to twist to the left is counterbalanced by the tendency of the right-spiraled grain to distort to the right. Of course, any unevenness in the twisting forces compels the pole to move in the direction of the dominant stress (fig. 2).

The spirality measurements are shown graphically in figure 3. These graphs support the counterbalance stress hypothesis. Those poles that contained both right- and left-spiraled grain generally twisted less (pole numbers 2 and 39) or twisted in the direction of the dominant stress (pole numbers 28, 7, 21, 20, and 23). In those poles having grain spiraled to the left only (numbers 34, 36, and 5), the angle of spiral appeared to be the controlling twist factor. The greater the slope-of-grain angle, the greater the amount of twist in the standing pole.

Figure 2. --Schematic showing counterbalanced internal left spiral grain (A) and external right spiral grain (B). Such a pole would be able to resist the tendency to twist and would remain straight in service.

Interpretation of Studies

These studies have pointed up several practical considerations concerning spiral grain and twisting in poles:

1. They have emphasized again that spiral grain is the normal growth pattern in trees and that grain in young trees tends to spiral to the left, to straighten out as the tree grows older, and finally tends to spiral to the right.
2. No method of detecting spiral grain was found in live trees or unpeeled poles by means of surface characteristics.
3. Direction and slope of grain may be correlated to some extent with growth rate. Spirality to the left tends to be associated with fast growth and to the right with slow growth. Since this is true, slope of grain may be controlled to some extent by silvicultural manipulation of stand density. However, correlation of grain angle with growth rate needs further investigation.
4. Twisting of poles in service was definitely correlated with spiral grain. Poles with severe left-hand spiral tended to be the bad twisters. Poles with right-hand spiral usually were more stable, with respect to twisting, than straight-grained poles. The cause of this difference was determined to be the internal grain structure. Poles with surface left-hand spiral contained left-hand spiraled grain from the center of the pole out to the surface. Poles with surface right-hand spiraled grain usually contained left-hand spiraled grain near the pith and right-hand spiraled grain near the surface. The result was counteracting twist forces and little net twist.
5. Proper seasoning might stabilize poles having severe left-hand spiral and make them satisfactory for use in pole lines.
6. Spiral grain specifications for poles need to be revised.

Figure 3.--Spiral grain at intervals from pith of sections from top, mid, and butt portions of 10 dissected poles from the Newport pole farm.

SUMMARY

Producers and users of utility poles have long been plagued by the twisting of some poles after installation. Between 1952 and 1960, six studies were made with the cooperation of four pole-producing companies to determine (1) frequency of spiral grain in poles, (2) how to detect spiraling in unpeeled poles, and (3) the part that spiral grain plays in the twisting of poles. The five studies reported in this paper were all of western larch, but the results are believed to be generally applicable to other species.

The study of cause of twisting of poles soon pinpointed spiral grain as a major cause. In 290 poles in four power transmission lines, left spiral grain occurred about three times as frequently as right spiral, and poles usually twisted in the same direction as their spiral grain. Left-spiraled poles usually twisted more than right-spiraled poles, and all severe twisting was associated with severe spiral grain on the pole's surface. Well-seasoned poles twisted less than unseasoned or briefly seasoned poles.

Results of a study aimed at finding a practical method of detecting spiral grain in poles before debarking were disappointing. Neither of two methods tried gave consistent success.

The study of frequency of spiral grain (based on 800 poles) showed two-thirds with left spiral and one-third with right spiral. However, the spiral was so slight in 48 percent of the poles that they could be classed as straight grained. Severe spiraling was chiefly left hand. Variation in slope of grain along the pole's length was common, and maximum divergence from the longitudinal occurred most frequently near the top.

The position of a tree on a slope had no apparent effect on either the direction or severity of spiral grain, but both direction and severity of spiral grain appeared to be highly correlated with stand density. Trees in open stands (with long crowns and rapid growth rate) tend to have grain that spirals to the left; the opposite was true for trees in very dense stands.

The study to determine correlation between pole twisting and spiral grain showed that straight-grained poles and those with right-hand spiral twisted less than poles with left-hand spiral, irrespective of amount of seasoning. Left-spiraled poles twisted most, and twist was in the same direction as spirality. Dissection showed that right-spiraled poles generally contained left spiral grain inside the pole that counterbalanced the tendency toward right-hand twist. Left-spiraled poles contained no such counterbalancing force.

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